Results from a subkeV energy threshold spherical gazeous detector for light Dark Matter identification

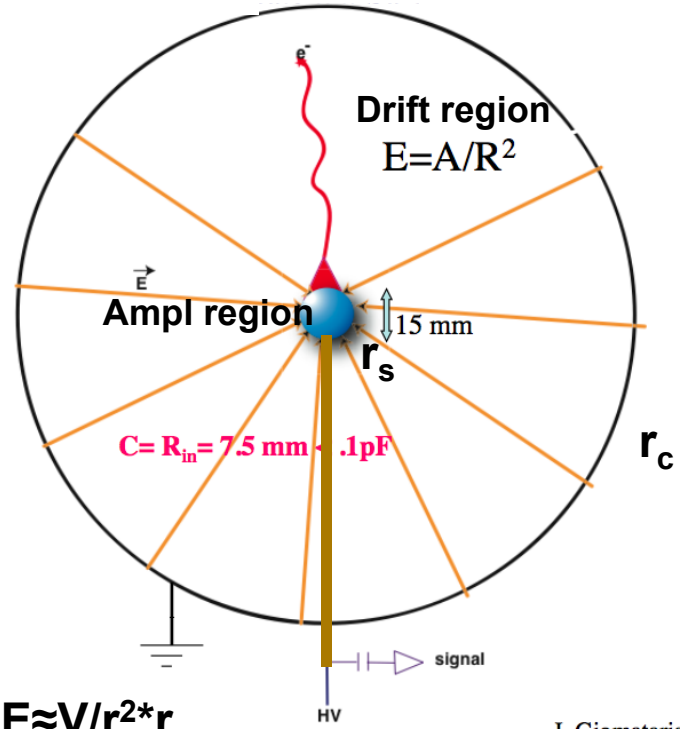
G Gerbier IRFU Saclay

+ **I Giomataris**, J Derre, **P Magnier**, **A Dastgheibi**, D. Jourde, M Gros, E Bougamont, XF Navick, T Papaevangelou, **J Galan**, *G Tsiledakis* **IRFU**
P Loaiza, T Zampieri **LSM**

Principles of detector
Results of calibrations at low energy
Preliminary results in low RA environment
Prospects : physics / development

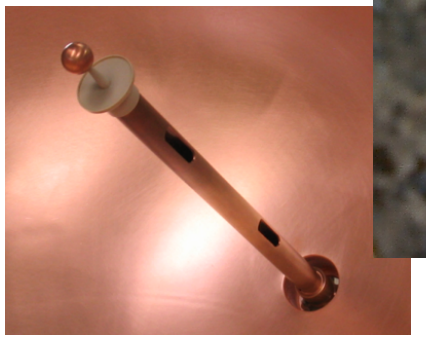
September 9th 2013
Monterey, TAUP2013

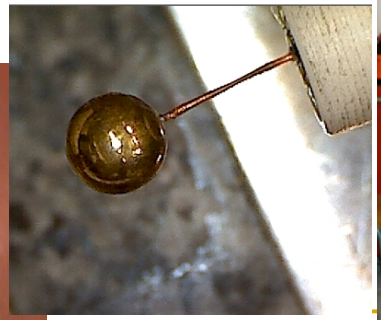
Spherical Proportional Counters



$E \approx V/r^{2*}r_s$
for $r_c >> r_s$

I. Giomataris





- Sphere cavity + spherical sensor + HT
- => Low threshold (low C), does not depend on size
- Fiducial volume selection by pulse risetime
- Flexible (P, gaz)
- Works in sealed mode
- Large volume => 10's kg possible
- 2 LEP cavity 130 cm Ø tested
- Digitisation at 2 MHz + soft trigger

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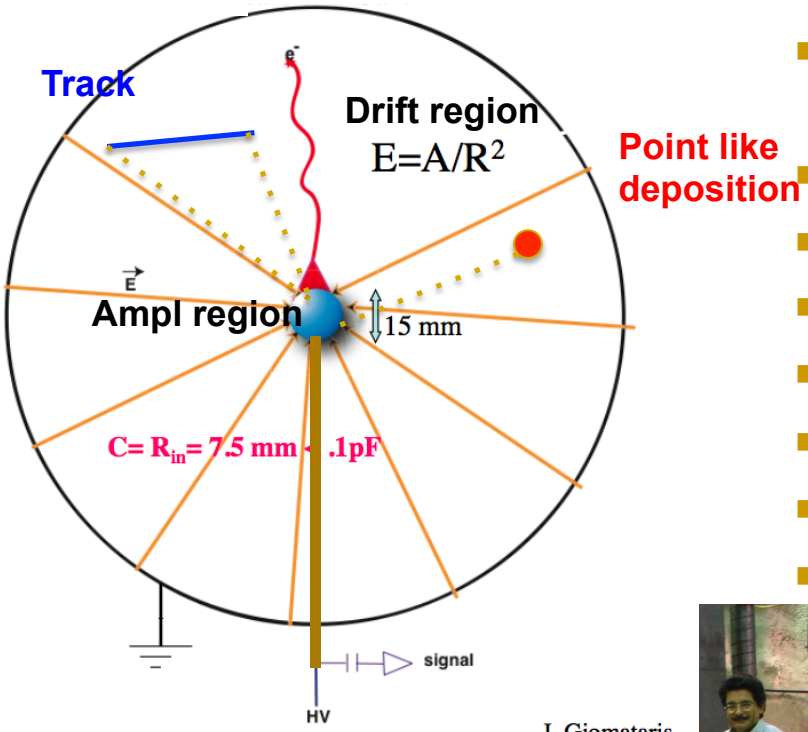

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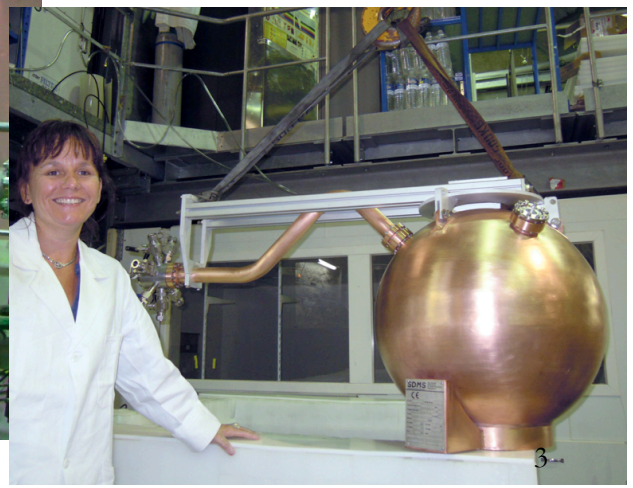
- 1 low activity 60 cm Ø in operation @ LSM

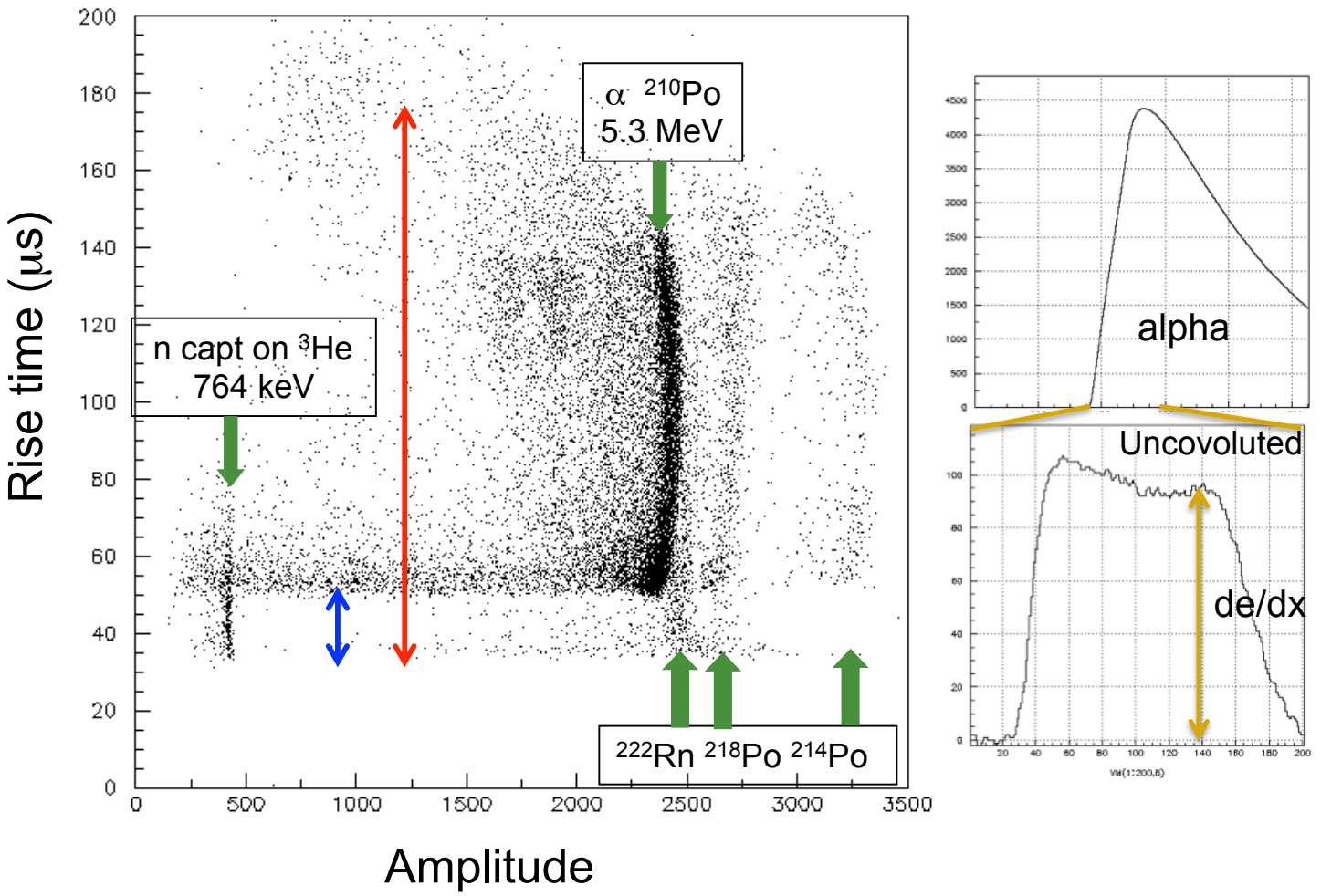


Run with Ar/CH_4 + 3g ^3He @ 200 mb SPC 130cm Ø @ LSM

NB: no start
=> risetime records place and/ or history of energy deposition

If **point like** energy deposition, rise time depends only on radius of interaction (diffusion)

If **track**, rise time depends on orientation of track, ie on difference of drift times



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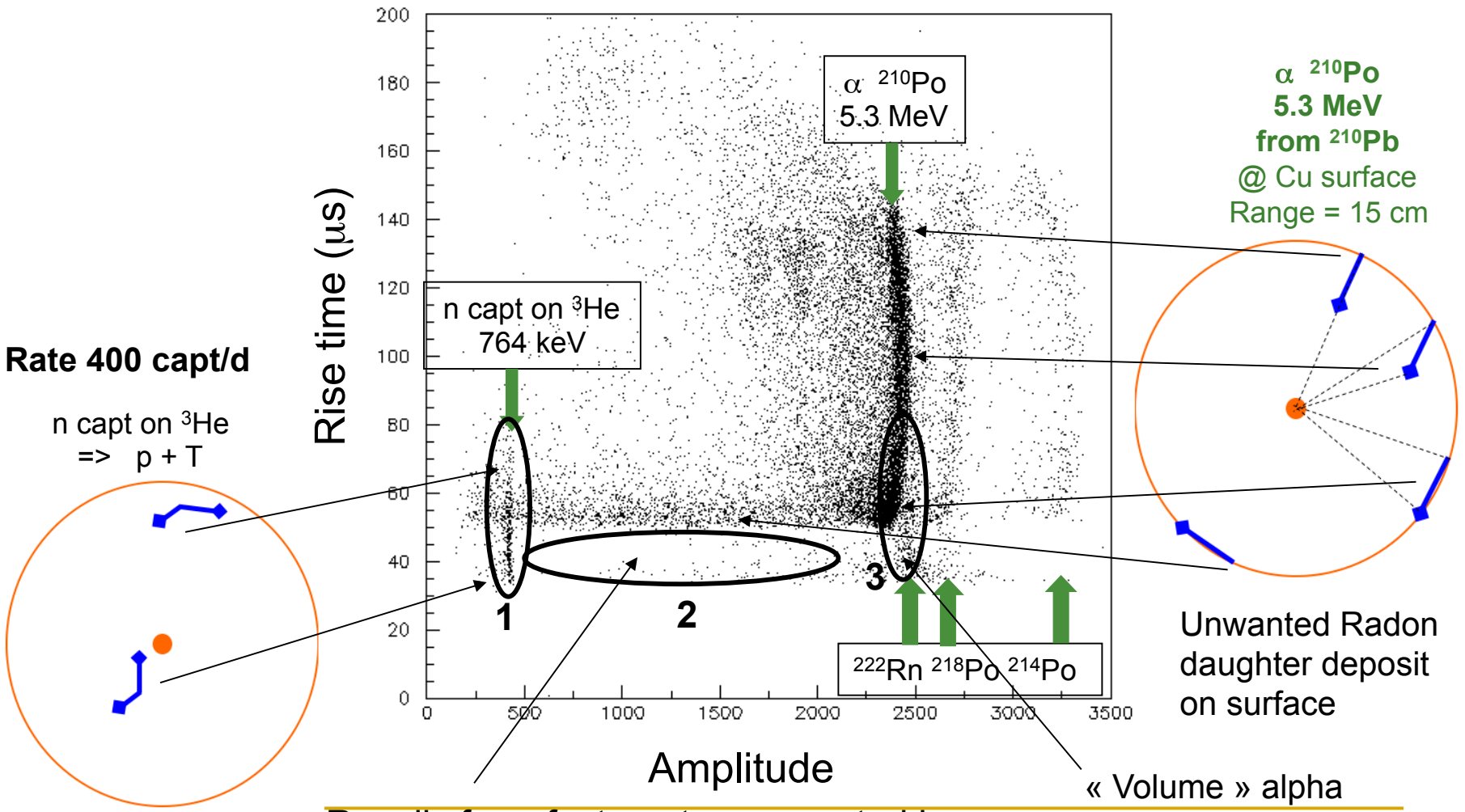
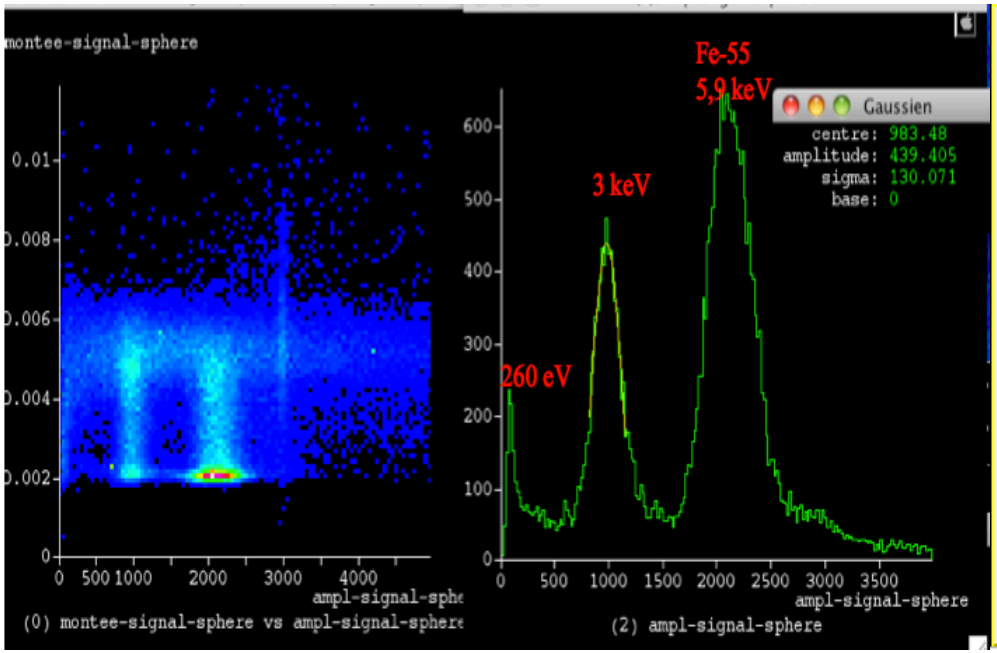
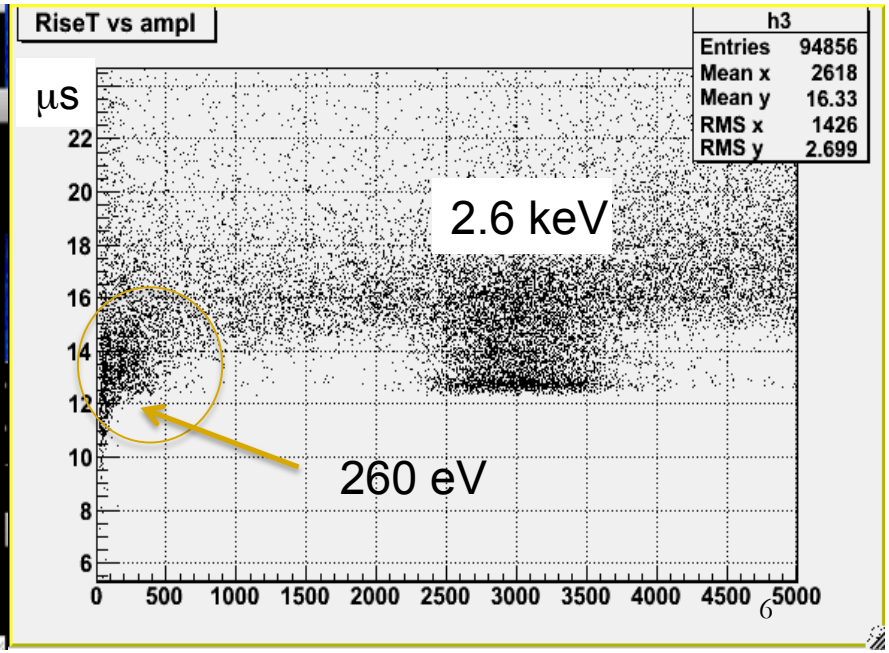
SPC 130cm Ø @ LSM



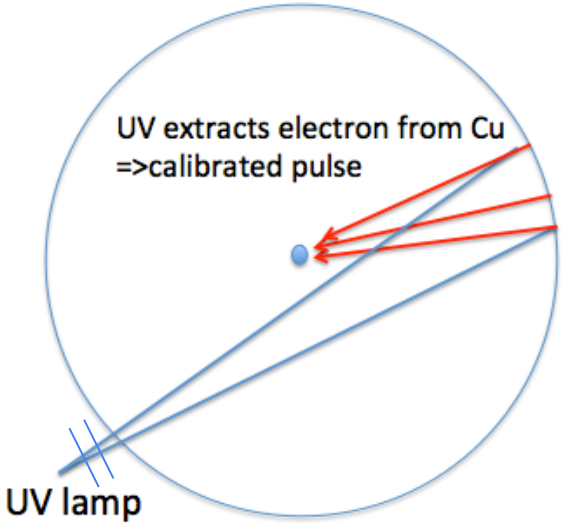
Going to low energy : calibration with ^{37}Ar source for volume response (SPC 130cm Ø @ Saclay)

- ^{37}Ar, EC, 35 days lifetime, Kα 2.6 keV and Lβ 260 ev
- Source made by n,α from Calcium salt powder irradiated with fast neutrons
- => Calibration show homogenous volume response

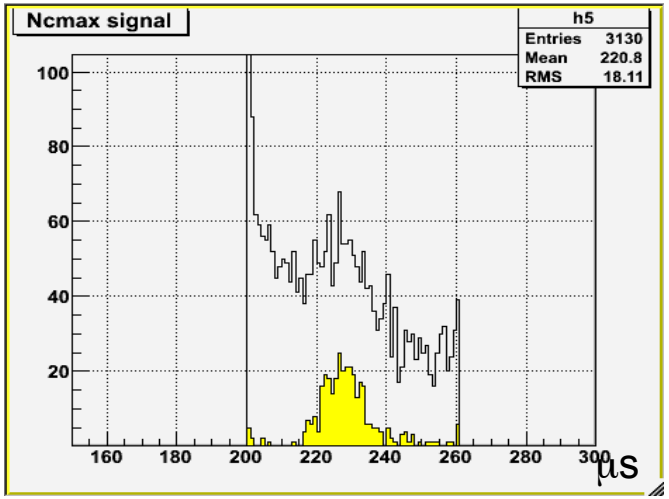




Calibration with UV flash pulsed lamp for single electron response

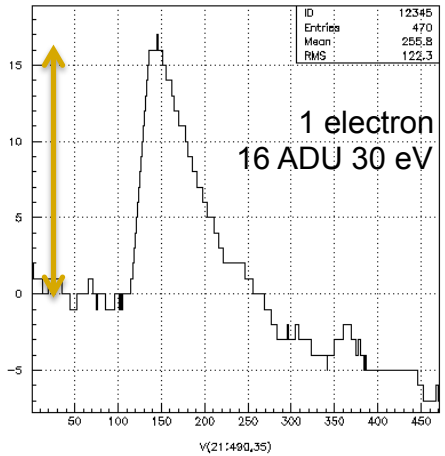


250 mb, Ar+2%CH4
HV = 3100 V
14 mm sensor

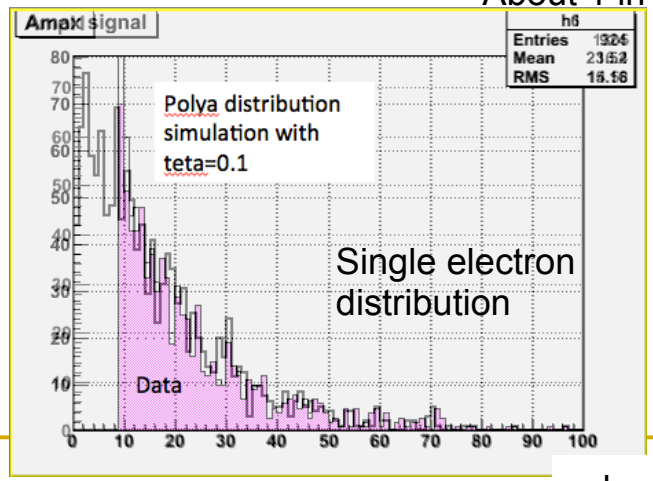


Delta time (UV-sphere pulse)
Look for pulse in 200-260 μs window
About 1 in 10 => single electron response

Pulse shape



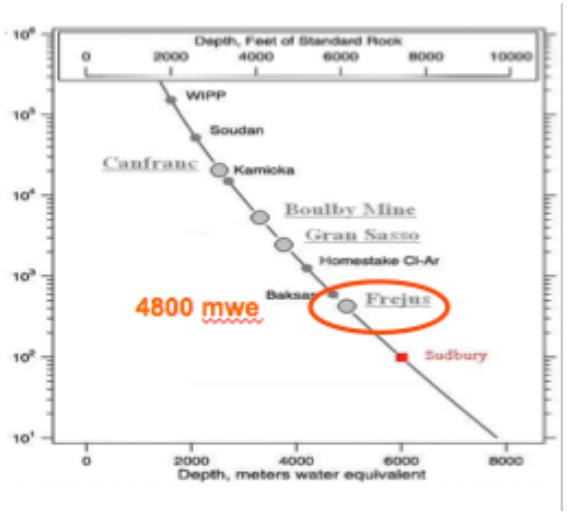
Trigger @ 10 ADU

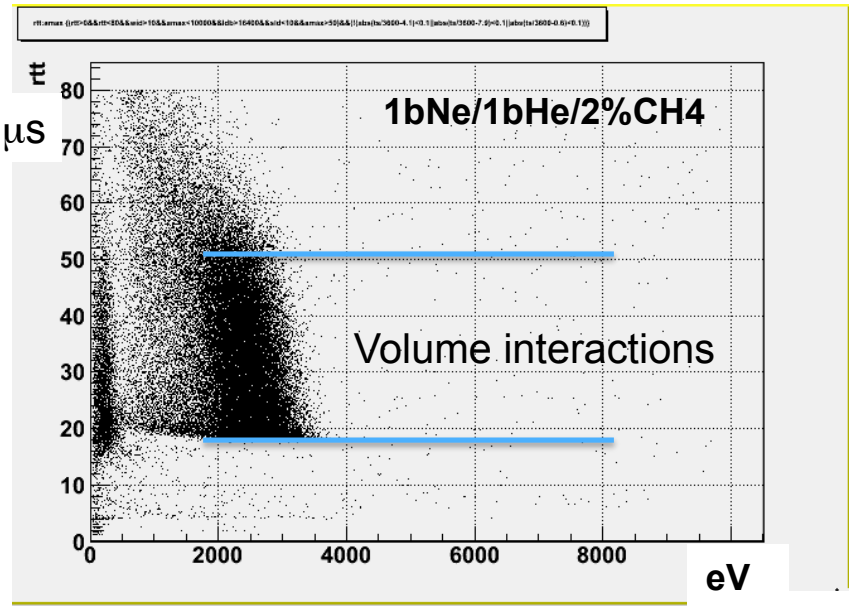


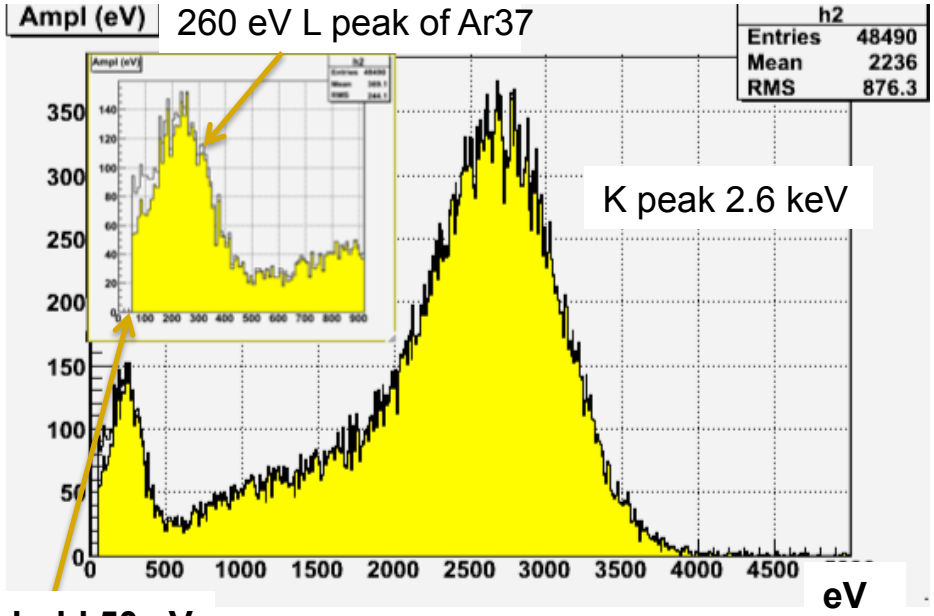
Trigger efficiency for single electron = 54 %
NB : single electron in Ar gaz w ≈ 30 eV
=> Threshold = 20 eV

Light dark matter search : low activity 60 cm Ø prototype @ **LSM** in Pb/PE shield

- In test since september 2012
- Test of sensors from 14 mm to 6 mm
- Reduction of RA contaminants
- Commissionning runs
  - Argon (but ^{39}Ar intrinsic radioactivityy)
  - Neon @ 2-4 bars
  - Neon/He 50/50 @ 2 bars







Threshold 50 eV

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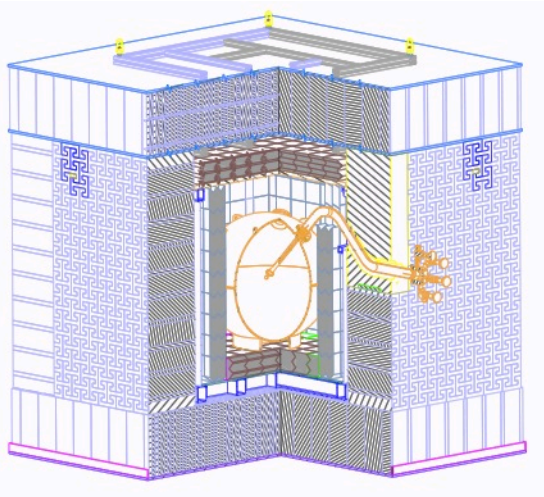

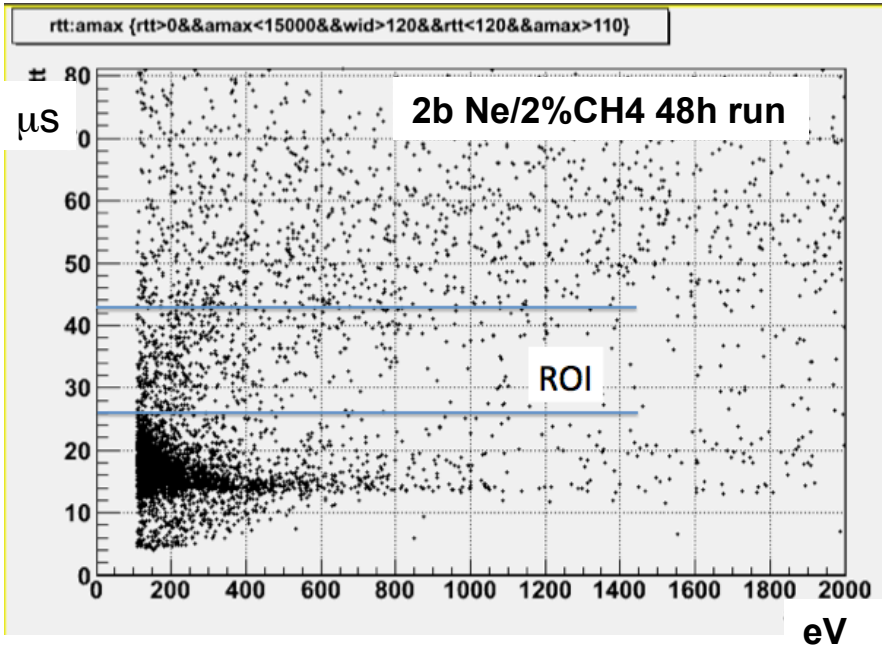

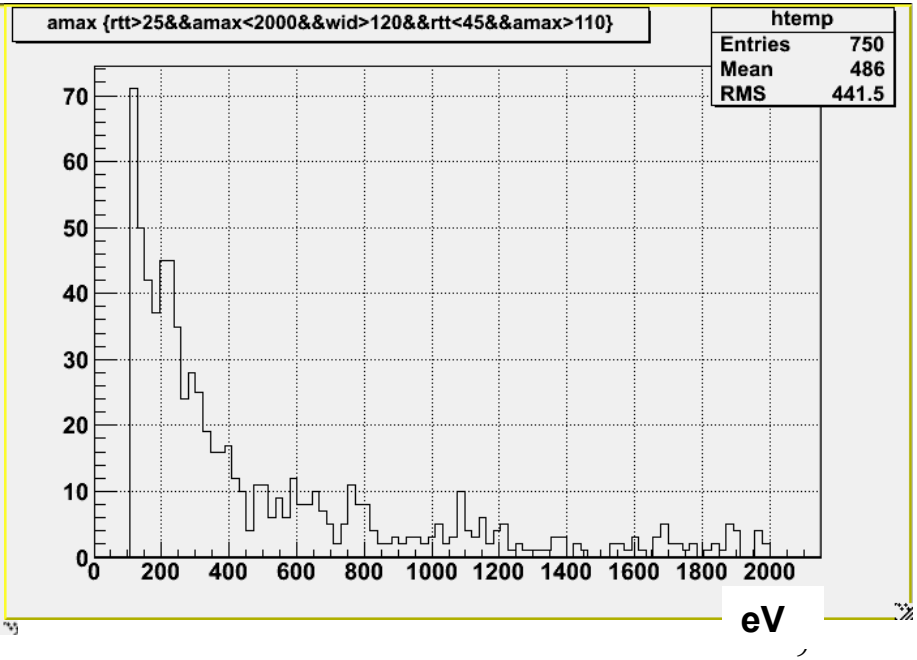

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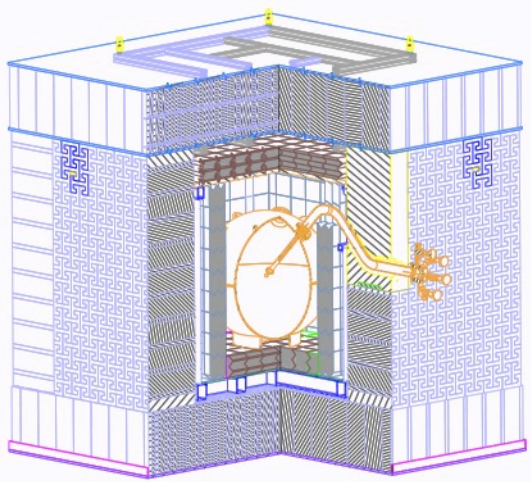
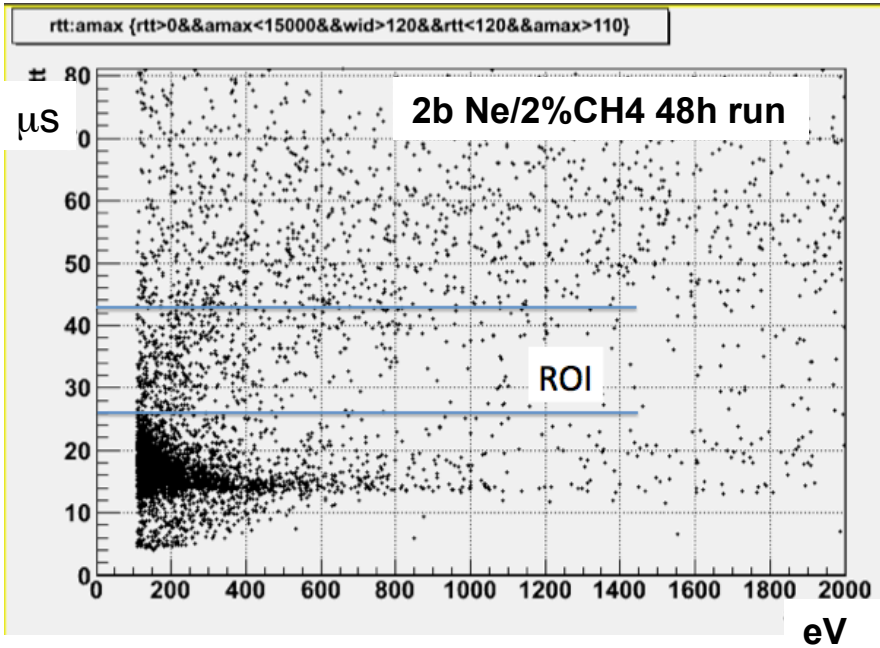
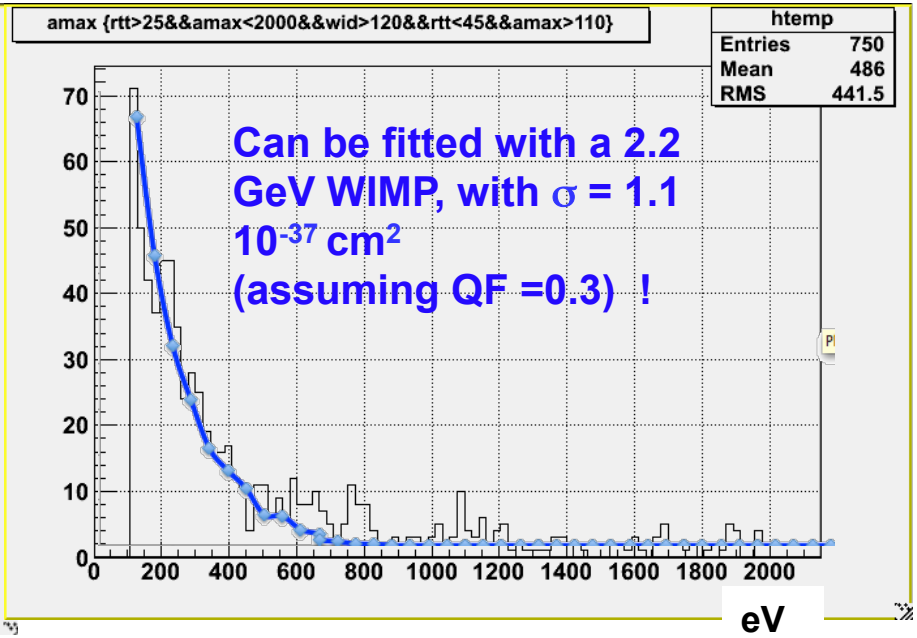
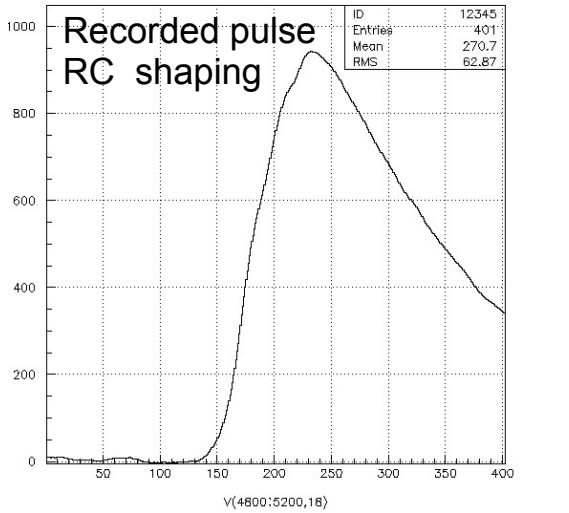
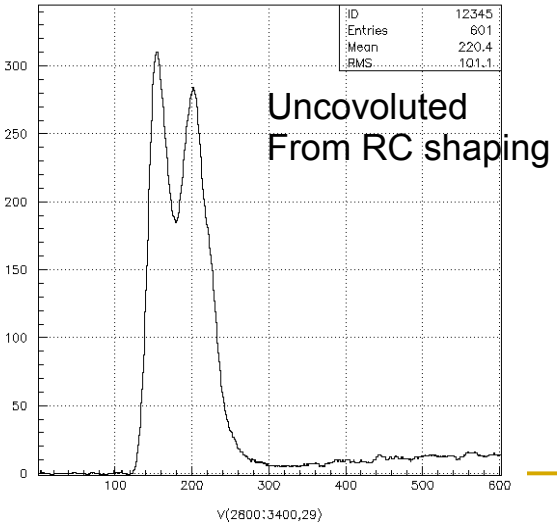




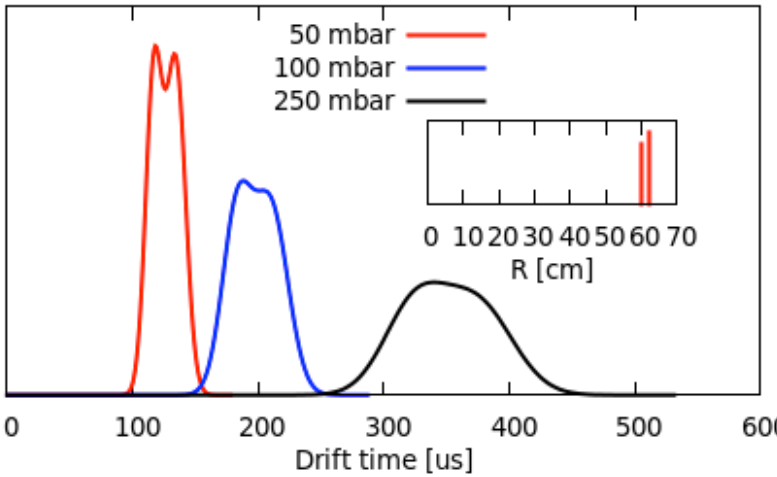


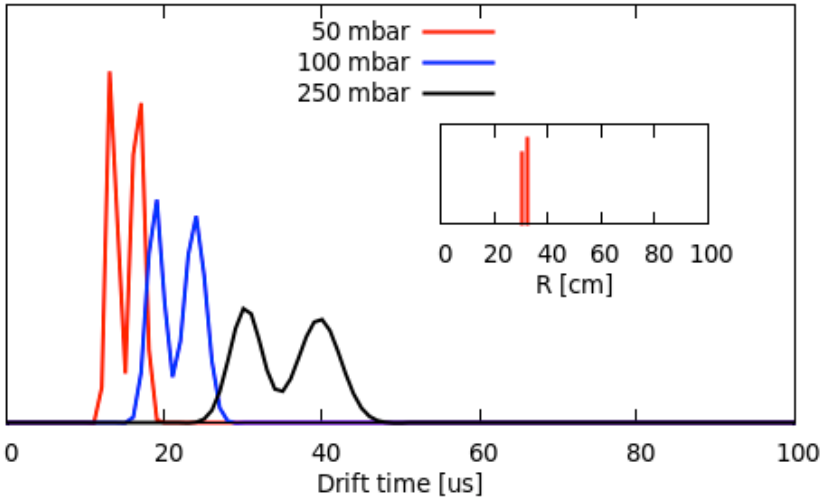
Additional discrimination through single/multiple energy deposition





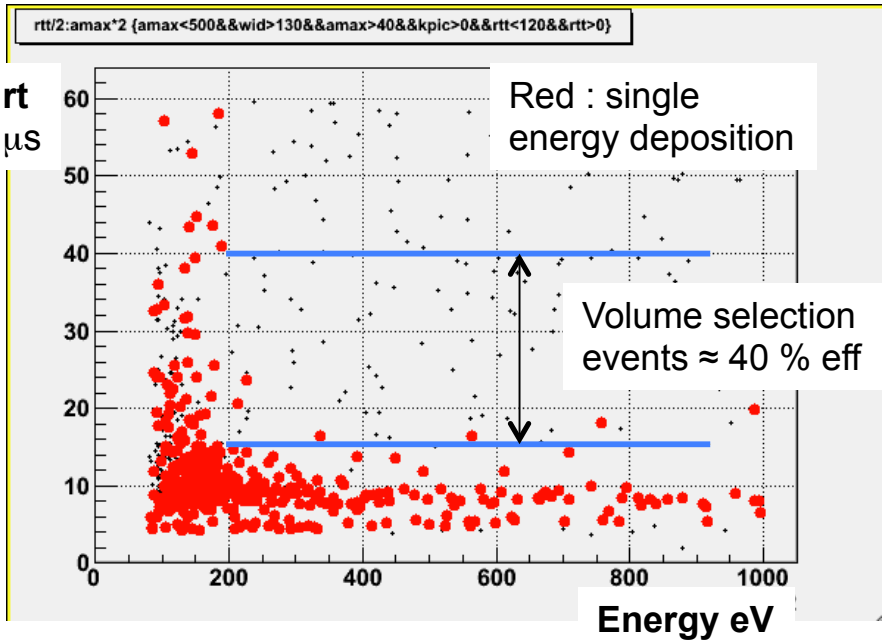
Simulation by J Galan

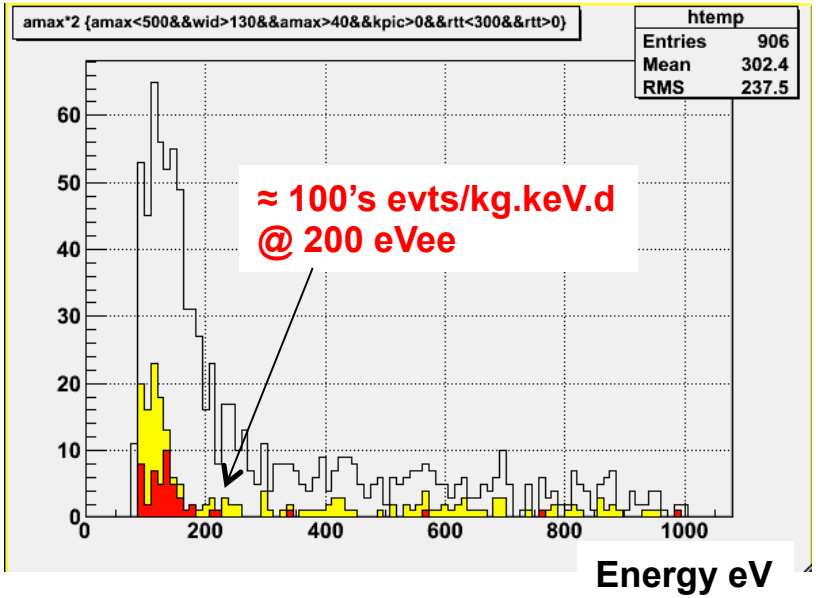




Test run with Ne (2bars)+He (2bars) 8h

He gives longer drift times => better identification of multiples



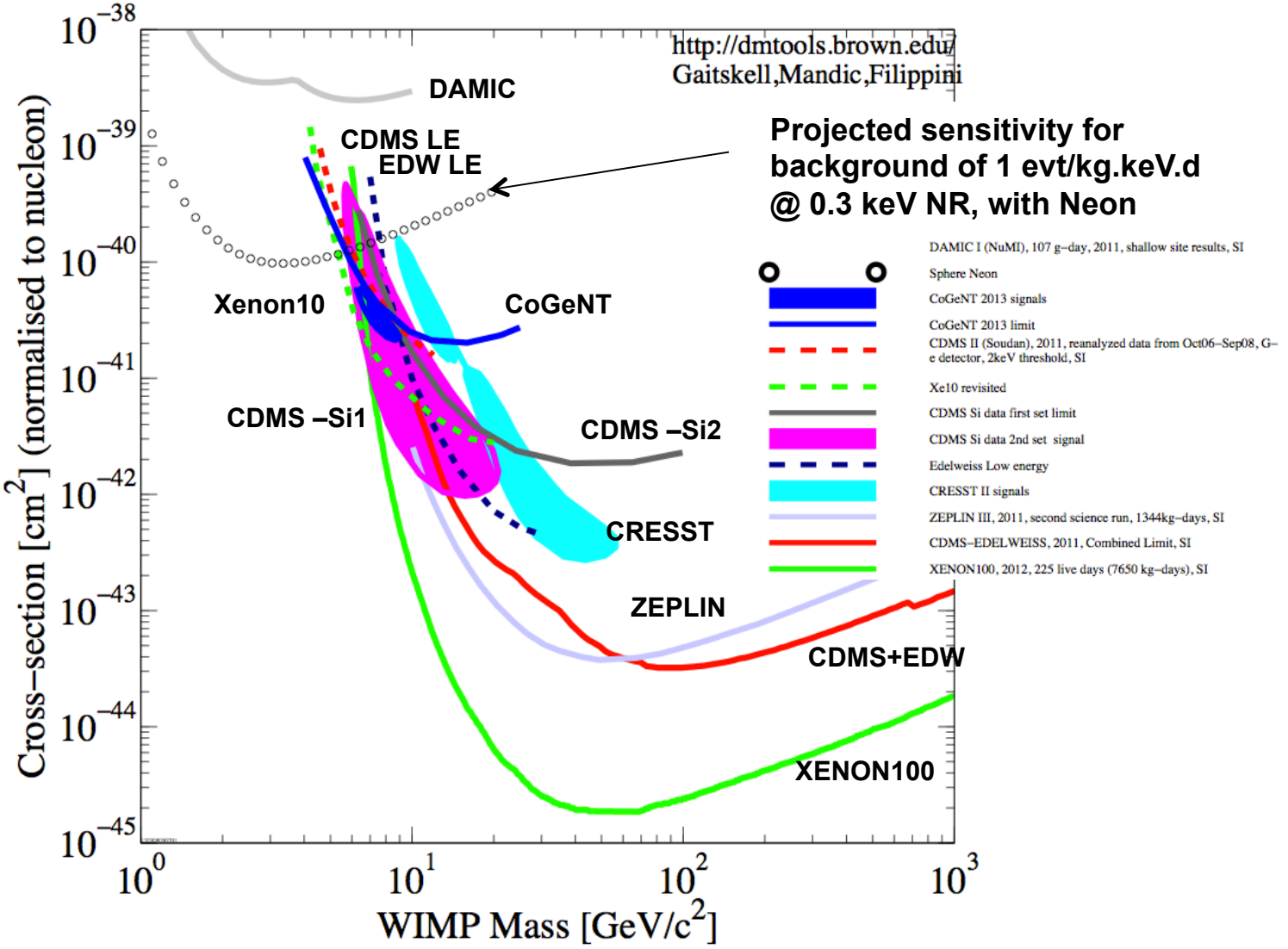


Preliminary

⇒ Studies in progress:

- refined pulse analysis
- calibration with fast neutron
- simulation of pulse shapes of electrons and neutrons
- Reduce RA contamination (alpha from ^{210}Po too high by factor 100)
- …

Sensitivity curves for light WIMP's



Other applications

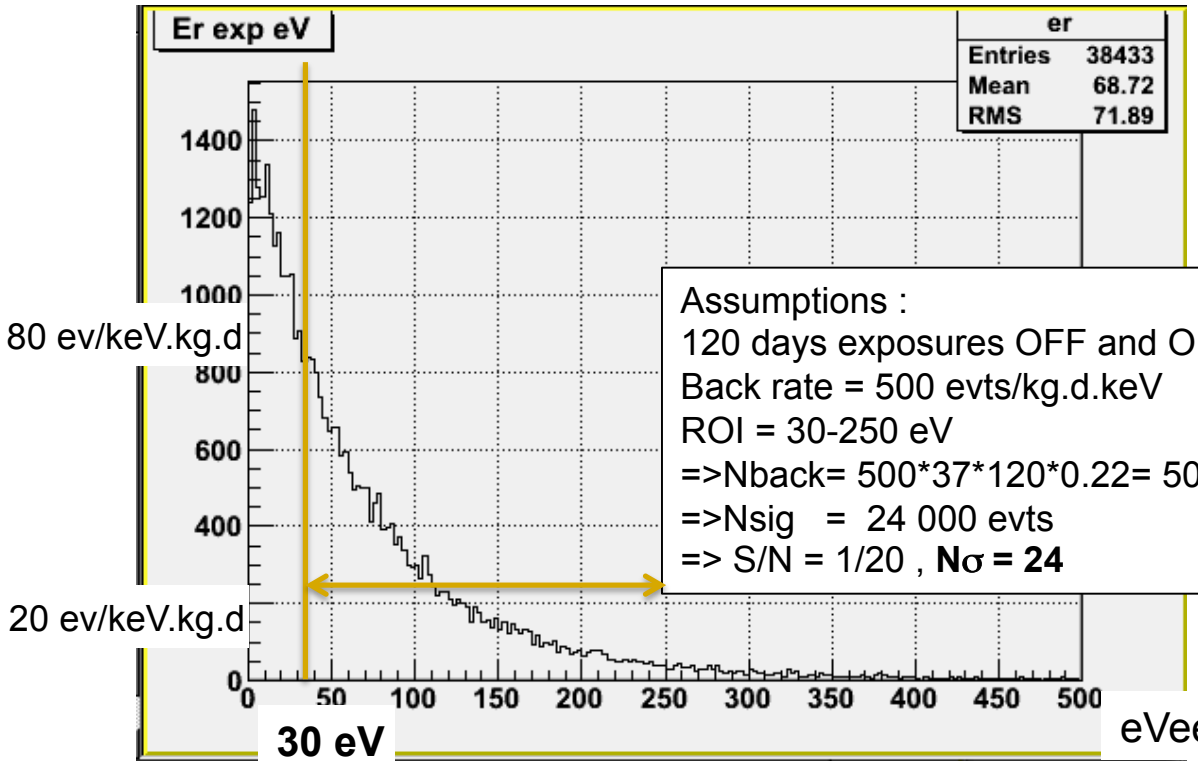
- **Axion Like Particle detection** : (decays in 2 photons inside sphere volume) motivation : solar corona temperature problem **L. Di Lella, K. Zioutas, Astropart. Phys. 19 (2003) 145**(J Galan)
- **Thermal and fast neutron detection** : interest : containment of products of capture eg He3, other gaz studied
- Network of 4m Ø spheres for **SuperNovae neutrino detection** through coherent scattering (about 10 evts for SN @10 kpc for 10 atm Argon =600 kg)
- Measurement of **neutrino coherent scattering at reactor** …

Measuring coherent neutrino scattering at nuclear reactor within reach

- Simulation of expected spectrum from nuclear reactor, on Ar, with quenching factor and instrumental response to single electron
- Normalisation to experimental reactor 70 MW
- Sphere of 2 m diam, 5 bars

Parameters			
Power of reactor		0,07	GW
Distance to core		7	m
Radius of sphere		1	m
Pressure		5	atm
Gaz	argon	37,4	kg
Signal nucoh >=2 e		**198**	**evts/day**
Delta E : 2-6e		0,12	keV

Evis >30 eV



Assumptions :
120 days exposures OFF and ON
Back rate = 500 evts/kg.d.keV
ROI = 30-250 eV
=>Nback= 500*37*120*0.22= 500 000 evts
=>Nsig = 24 000 evts
=> S/N = 1/20 , **Nσ = 24**

A proto collaboration

New **E**xperiments **W**ith **S**pheres

Neutrino **E**xperiments **W**ith **S**pheres

New **E**xperiments for **W**imps with **S**pheres

CEA-IRFU/Saclay (GG,IG),LSM (F Piquemal), **Aristotle University of Tessaloniki** (I Savvidis), **University of Ioannina** (I Vergados), NCSR **DemoKritos** (G Fanourakis), **Hellenic Open University** (S Tzamaria)
University of Tsinghua Beijing (C Tao), **Shanghai Jiao Tong University** (K Ni),
IHEP-Beijing (Z Wang, C Yang)
University of Saragoza (I Irastorza), Livermore (JR Armendariz)

- **Projects under study**
- 4 m Ø underwater 2000 m @ Pylos @ few 100s bars for SN
- **2 m Ø underground low activity for DM and ALP search shielded in water tank**
- Perform ν coherent scaterring expt
- Develop neutron spectrometer
- Develop sensors + scint light detection
- **+ Great tool for training to particle detection !**

Conclusions/outlook

- First studies show that spherical gaz detector :
  - can indeed reach single ionisation electron sensitivity @ P>1 atm
  - has background rejection capabilities and redondancies to identify signal
  - is well adapted for low mass WIMP search 0.1 to 5 GeV
  - has potential for neutrino coherent scattering detection & other LE rare processes
- Developments to improve performances of current prototype
  - Decrease high radioactive contamination : surface Rn descendants
  - Improve pulse shape analysis : calibration, templates…
  - Perform calibration with neutron/Ar37
  - Perform quenching factor measurements in <keV region (D Santos installation at Grenoble)
- Going to larger volume/pressure :
  - NB : 4 m diameter sphere can hold 600 kg of Ar @ 10 bars
  - Decoupling of amplification from drift : new ideas about sensors currently tested
  - … lot to develop and discover